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ABSTRACT

Educational psychology has indicated that prior knowledge is a potentially important educational variable. Recent and earlier research in educational psychology has shown that 30 to 60% of the variance in study results could be explained by this variable. Insight into these factors should influence the return on education. A common theoretical frame regarding explanatory theories and concepts, considering different sorts of prior knowledge and individual differences in prior knowledge states, could lead educational psychology research to previously acquired knowledge and experience. Further research should concentrate on such a framework, building on earlier results. This report gives an overview of research on the effect of prior knowledge on learning and theories that offer an explanation for the facilitating effect of prior knowledge. An exploration of the concept "prior knowledge" is made, largely on the basis of the English language literature. Attention is also paid to the expert-novice paradigm. Four figures and one table illustrate the discussion. (Contains 116 references.) (SLD)

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The 'Prior Knowledge State' of students and its facilitating effect on learning: theories and research

F.J.R.C. Dochy

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F.J.R.C. Dochy

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Summary

Educational psychology has indicated that prior knowledge is a potentially important educational variable. Recent and earlier research in educational psychology has shown that 30 to 60 per cent of the variance in study results could be explained by this variable. Insight into these factors should influence the return on education.
A common theoretical frame regarding explanatory theories and concepts (different sorts of prior knowledge and individual differences in prior knowledge state) could serve educational psychological research into previously acquired knowledge and experience.

Further research in this area should be situated in this theoretical framework and build upon earlier results.
This report gives an overview of the research into the effect of prior knowledge in learning and the theories flowing from it which offer an explanation for the facilitating effect of prior knowledge. Further, largely on the basis of the English language literature on the subject, an exploration of the concept of 'prior knowledge' is made and of various types of prior knowledge. Finally attention is paid to the expert-novice paradigm.

1. The importance of prior knowledge

The work of Ausubel is certainly not the first to direct attention to the importance of prior knowledge. In any event, his work has led to renewed psychological interest in learning in institutionalized educational contexts. Ausubel highlights an important moment in the development of a subfield within a branch of psychology that is generally called educational psychology (Lodewijks, 1983). In his basic text 'Educational Psychology: a cognitive view' he writes unhesitatingly about the crucial role of prior knowledge in learning: "If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." (Ausubel, 1968). This involves a tripartite assumption (Lodewijks, 1983) i.e.:

- that prior knowledge is the most important variable in educational psychology;
- that the degree (content and degree of organization) of prior knowledge of a student must be familiar or measurable for the achievement of optimal learning;
- a learning situation is optimal to the degree to which it accords with the level of prior knowledge.

Recent literature in educational psychology however indicates that there has not been much advance on this statement. Research into the establishment of the level of prior knowledge has been infrequently undertaken or not at all. In recent years within research into cognitive processing activities, an increasing interest can be detected in the role that student's prior knowledge plays in acquiring new information (Anderson, Spiro and Anderson, 1978; Bower, Black and Turner, 1979; Mayer, 1980; Pinchert and Anderson, 1977). Anderson (1978) writes: "The knowledge a person possesses has a potent influence on what he or she will learn and remember...". The conclusion of Beukhof is worthy of note: "Comprehension is best represented as an interaction of content in text and the reader's prior knowledge". One of the foremost results of recent research in cognitive psychology is the consciousness that 'old' knowledge plays an important role in the acquisition of 'new' knowledge (Vosniadou and Brewer, 1987; Anderson, Spiro and Montague, 1977; Bransford, 1979; Brewer and Nakamura, 1984).
On the other hand, the amount of knowledge has a substantial impact on the learning process (Chi, Glaser and Rees, 1982). Knowledge that the learner already has about a particular subject appears to exercise a considerable influence on the manner in which and the degree to which new information is understood, stored and can be used.
Furthermore it is accepted that both the acquisition of

knowledge and the learning of skills is dependent on the entry behaviour. (Neisser, 1976; Dochy and van Luyk, 1987).

The fact that prior knowledge has been demonstrated to be a potentially important educational variable is shown in the research of van Weeda (1982) inter alia. He found that knowledge measured prior to a course, explained, on average, no less than 50% of the variance in the post test scores. Comparable results were reported by Bloom (1976). Lodewijks (1981) found a correlation of 0.60 between the assessment the students made of their prior knowledge and their actual performance. The results of the research into the influence of variables on study results demonstrate that prior knowledge explains between 30 and 60 per cent of the variance in study results. Research demonstrates that prior knowledge is an important educational variable (Schmidt, 1987).

Figure 1 gives an overview of the relative influence of the different factors in learning.

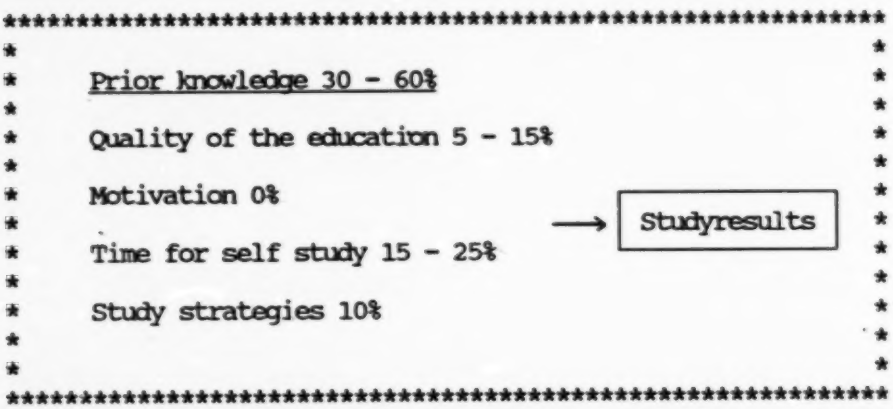
Prior knowledge 30 - 60%
Quality of the education 5 - 15%
Motivation 0%
Time for self study 15 - 25%
Study strategies 10%
Studyresults

Figure 1: An overview of the educational variables and their relative influence on study performance (after Schmidt, 1987).

In contradistinction to the influence of prior knowledge in the learning process, in educational practice, relatively little account is taken of the prior knowledge and experience of students. According to De Wolf (1985) it is very seldom that true account is taken to prior knowledge in the grading of subjects in terms of time and content. The most that can be said is that some allowance is made for prior knowledge that is largely assumed or, in a few cases, tested. A limited synopsis of the theories and research on prior knowledge makes this position clear.

2. Theories and research results on the use and influence of prior knowledge.

In day-to-day life, we would appear to be increasingly confronted with the fact that we retain information better when we know something about the subject, than when we do not.
Although this was known to educational psychologists, until very recently there was little or no research into the use and influence of prior knowledge.
On the contrary: attempts were made to exclude the effect of prior knowledge as far as possible, for example by using nonsense syllables in experimental research situations. This was done in the hope - that has since be demonstrated as futile - that fundamental patterns in the learning process could thus be studied in isolation (Van Dam, 1979). When prior knowledge in this artificial and restricted framework eventually did surface, it was in a transfer experiment which investigated the influence of learning a series of syllable pairs on learning a second series (Peeck, 1979).

However, a number of attempts have been made to actively manipulate prior knowledge or to apply it in the learning process. These relatively recent attempts show that the activation of existing cognitive structures generally exercises a facilitating effect on the learning task. This empirically demonstrated phenomenon awaits sufficient explanation in more applied research. Among other things, it is unclear which cognitive process (or processes) are to be held responsible for this, and how use may be made of this facilitating effect in concrete educational situations with an increased return and improvement of quality as an objective. In the literature, a number of theories have been advanced in explanation, primarily on the basis of experimental research.
A number of approaches, some of which have already been presented by Schmidt (1982), are distinguished here:

1. The restructuring theory.
2. The elaboration theory or 'multiple redundant retrieval paths' theory.
3. The accessibility theory.
4. The selective attention hypothesis.
5. The availability theory.
6. The retrieval-aid theory.
7. The schema-transfer theory.
8. The representation-saving theory.

2.1.: The restructuring theory:

First there is restructuring theory, which assumes that experimental subjects, as a consequence of a period of activation, organize information in the long term memory in a different way from experimental subjects who have no prior knowledge (Matthews, 1982). Although the structure of the original criterion text could be found in the protocols of both groups, the groups differed from one another in a manner in which they had organized the information. A possible explanation of this effect is given by Rothbar et.al. (1979) by means of the 'encoding specificity' theory (Crowder, 1976; Tulving and Thomson, 1973). This theory posits prior knowledge leading to a 'category label' which is activated and to which each specific element is added when it is stored in the memory. The information already present would therefore have an influence on the manner in which new information is coded. A derivative of this restructuring theory is the hypothesis that students with a great deal of prior knowledge process new information by means of a different cognitive structure from those with little domain-specific prior knowledge.

2.2.: The elaboration theory:

A second option is that prior knowledge stimulates the production of significant elaboration (Craik and Lokhart, 1972; Craik and Tulvin, 1975; Anderson, 1976; Mayer, 1980; Reder, 1980).
Elaboration is the enhancement of information by the development of relations among the ideas from the text (on the basis of prior knowledge) and between an element in the text and prior knowledge. For this reason Mayer (1979) had referred earlier to a similar 'assimilation theory' in which "relating new, potentially meaningful material to an assimilative context of existing knowledge" was regarded as the core of learning. The 'subsumption theory' of Ausubel (1960, 1968)pointed in the same direction: "for effective learning, people should possess and use meaningful assimilative contexts to integrate the material". The enhancement of information by elaboration based on prior knowledge leads, according to Anderson and Reder (1979), to the development of 'multiple redundant retrieval paths' in the resulting cognitive representation. The presence of such retrieval paths is supposed to facilitate learning in the sense that the recall of coded information is made easier. The same can be assumed for the production of interference on the basis of prior knowledge. Interference is a meaningful supplement to a text which adds meaning to the incoming

information and functions as an expectation pattern in respect of information still to be processed (Schank and Abelson, 1977). The difference between this and elaborations lies in the conscious activity which produces the latter. It is also important that the elaboration process leave traces in the recall. As experimental subjects can no longer distinguish the actual information from their elaborations on it as a result of the manner in which they processed the information, the amount of interference in recall increases (Bartlett, 1932); Frederiksen, 1975). The presence of such retrieval paths would facilitate learning in the sense that the recall of coded information would be easier.
This theory has often been supported in the literature (Gagné, 1978). Johnson (1973) found that "linguistic units rated high on meaningfulness were recalled better than those rated low on this dimension". Two criticisms of this research are possible:
meaningfulness would seem to be arbitrary dimension for prior knowledge and it has been shown that the value attached by experimental subjects to the meaning of a proposition was an imaginary value thus not valid (Paivio, 1971). Although the elaboration theory gives a possible explanation for the positive effect of prior knowledge on learning, this mechanism has not been either directly or explicitly demonstrated before. It is however true that the research of Stein, Bransford, Franks, Owings, Vye and McGraw (1982) and Franks, Vye, Auble, Mezynski, Perfetto, Bransford, Stein and Littlefield (1982) has shown that learning in less successful students can be improved if they are trained to make consistent elaborations and to assess the relevance of self-generated elaborations.

2.3.: The accessibility theory:

The third theory concentrates on the speed with which information can be processed as a component of the return on learning. On the basis of the work of Spilich, Vesonder, Chiesi and Voss (1979) and Royer and Cable (1975) it may be posited that the activation of prior knowledge increases access to that knowledge during the learning process. This improved accessibility results in a lessening of the load on the working memory and (its capacity consequently increases), as a result of this more information can be processed per unit of time.
According to Spilich et al. (1979) people with increased prior knowledge are able to understand a text more rapidly because the prior knowledge is more easily accessed and the components of the new information are rapidly linked in this way. Spilich, Vesonder, Chiesi and Voss investigated how

students with differing level of prior knowledge about baseball processed new information on that subject. The use of a domain-specific area of knowledge, such as baseball, had the advantage that on the one hand the researchers were able to give a description of the subject matter using a strict terminology (in terms of goal structure, game states and game actions) and on the other hand that it was fairly simple to divide the students into a High Knowledge and a Low Knowledge group on the basis of a questionnaire after matching.
In this sort of prior knowledge research, it is virtually never possible to form a true control group without prior knowledge. The results of the research show that HK-students have a more highly differentiated knowledge structure than LK-students. They have more concepts at their disposal and above all a more highly differentiated system of relationships among these concepts. As a result of this they can identify the knowledge relevant information more rapidly and more accurately and perceive its relevant importance more quickly, with as a result more precise encoding and storage in the memory, facilitating the recall of data. Further, the HK-group can both qualitatively and quantitatively better anticipate what is likely to happen in a simulated game situation, and, in the retention of the information, they can make better use of the context so that richer and more highly integrated chunks of information are stored in the memory. This results in the prior knowledge available in long-term-memory being more easily accessed, consequently, in functional terms, HK-students have a relatively large working memory capacity in learning knowledge-relevant data (Peeck, 1979). This sort of procedure in research into the effects of prior knowledge on the perception and retention of prior knowledge-relevant information was also applied with remarkable results by De Groot,(1946, 1978) in his research into a chess player's thinking.
Zwarts' (1978) research results accord with the above mentioned findings. The research was directed at the influence of domain specific prior knowledge in ornithology. The difference between the HK-group and the LK-group was however greater in the free reproduction of a text than on recall with the help of fill-in questions. Anderson and Pichert (1978) believe that "accessibility of information is predictably affected by that prior knowledge". This sort of relationship is also demonstrated by Johnson and Kieras (1983) in their research on subjects in secondary education, for example history. This theory is incidently not distinct from the restructuring theory. The manner of organization particularly influences access to information in the long-term-memory in turn (Gardner and Schumacher, 1977).

2.4.: The selective attention hypothesis:

A fourth processing strategy that has some a priori plausibility in the explanation of the phenomenon is the selective attention. One thing that cannot be excluded is that people with more prior knowledge direct their attention selectively to passages relevant to prior knowledge in a text, which then receives a deeper level of processing. Prior knowledge activation is said in this sense primarily to fullfil a directive role (Reynolds, Standiford and Anderson, 1979; Rothkopf and Billington, 1979), in the sense that relevant information receives more attention (largely expressed in study time) at the expense of information that is not relevant to the problem or topic. Goetz, Schallert, Reynolds and Radin (1983) had experimental subjects read a text on an empty house and register per sentence how much time they spent on it in order to verify the selective attention hypothesis. As was the case in Anderson, Pinchert and Shirey's (1983) research, the task was to study a text either from the perspective of a potential buyer or from the perspective of a burglar. It was concluded that the information that best fitted the perspective would receive the most attention and would be best retained.
In a number of investigations similar discoveries were made, i.e. that consistent new information was better retained: Pinchert and Anderson (1977), Anderson, Spiro and Anderson (1978), Rothbart, Evans and Fulero (1979), Cohen (1981), Philips and Lord (1982), Anderson, Pinchert and Shirey (1983), Berman, Read and Kenny (1983).
Peeck, van den Bosch and Kreupeling (1982) revealed that the hypothesis could also be used to demonstrate that it was precisely inconsistent new information that was best retained. According to Peeck et al. experimental subjects pay selective attention to names that they don't recognize, this was in an activated condition in which they had to name American presidents and states. The fact that inconsistent new information is better retained was also confirmed by Hastie and Kumar (1979), Hastie (1980), and Srull (1981).
A number of explanations have been sought for the fact that selective attention is sometimes focused on consistent new information and sometimes on inconsistent information. Berman, Read and Kenny suggest that the nature of the task has an influence: when there is a greater demand on the archival memory and there is less useful general social prior knowledge available, inconsistent information is retained less well.
According to Berman et al. (1983) certain experiments conceal a number of elements. The relationship between consistent and inconsistent new information is in itself particularly important. They point to the fact that in experiments in which inconsistent information is best retained, the amount of acquired inconsistent information is relatively small in

comparison with the acquired consistent information.
Cohen (1981) notes that the tasks the experimental subjects are given are an influential factor.
One can think here of the differences described in the burglar and purchaser perspectives. Graesser, Woll, Kowalski and Smith (1980) confirm that use of a memory task as a dependent variable leads to the better reproduction of consistent information during a relatively long retention interval. In a memory task the search procedure in the memory is not made easier by 'cues' as in case of a recognition task and is accordingly under less retention pressure (Gerritsen, 1986). Inconsistent new information is therefore better reproduced in a recognition task (Graesser et al., 1980).

2.5.: The availability theory:

Pace (1978) did research into the influence of prior knowledge on information accessibility. She identified a number of topics which were classified on a scale from very well known to totally unknown for the experimental group. She wrote a text on each of these topics using the knowledge bases of the experimental subjects. Each experimental subject received each text and answered a number of questions on the subject. Pace concluded that the higher the level of prior knowledge the more questions would be correctly answered. Mathew's (1982) results also show that a suitable level of prior knowledge should lead to a higher level of retention. "Finally, prior knowledge will provide a conceptual-peglike construct, thus increasing the amount of information available in memory." (Matthews, 1982).

2.6.: The retrieval-aid theory:

Where the earlier theories were primarily directed at coding and storing information, this theory is directed at the retrieval phase. Anderson and Pinchert (1978) established that the activation of relevant cognitive structures after the reading of a text do indeed promote recall of that text and concluded that activation of prior knowledge also influences retrieval. Anderson, Pinchert and Shirey (1983) had experimental subjects read a description of an empty house. It appeared that a perspective imposed afterwards also had an influence on post experimental measurement. The positive influence of prior knowledge on retrieval was also found by Berman, Reid and Kenny (1983) and Cohen (1981). Rothbart, Evans and Fulero (1979) did not succeed in confirming this effect.
This theory is again supported by a number of explanations:

the retrieval plan explanation of Anderson et al. (1983), Philips and Lord's (1982) reconstructive processing and Berman, Read and Kenny's (1983) guessing bias idea. Anderson and et al. (1983) believe that experimental subjects look for certain information categories which fit into the actual scheme and from which the retrieval plan is constructed. According to Philips and Lord (1982) they give an explanation by means of reconstructive processing: experimental subjects remember some information that is no part of the text presented, but is consistent with the scheme(s) in which the new information is classified. The guessing bias explanation of Berman et al. (1983) is perhaps more arbitrary: experimental subjects who cannot remember particular information try to guess it on the basis of a given perspective.

2.7.: The schema-transfer theory:

This theory explains the facilitating effect of prior knowledge both in the storage of information and on retrieval by the presence of an appropriate schema for the textual information. A schema can be described as "an organized knowledge structure that guides perception" (Rumelhart, 1980). Owing to the fact that the structure for decoding already exists it only has to be related to the new information. Remembering by means of a "schematic knowledge base" can also operate in the same way. Rumelhart and Ortony (1977) suggest that one can conceptualize remembering as observing with memory as a modality. In this way a schema can act a guide for the recall. Graesser, Hoffman and Clark (1980) confirmed that prior knowledge of the relevant schema optimalized "prose memory performance". This does not mean that one can conclude that the learning of scholarly information could be better achieved by knowing relevant schemas. Schemas are, in concrete terms, often defined in terms of the stereotypical sequence of events which arise in simple narrative (Graesser, Robertson and Anderson, 1981), targeted activities (Chiesi, Spilich and Voss, 1979), or the subject structure of narrative depending on the content (Thorndyke, 1977). Scholarly writing is sometimes a mere summary of facts which has no clear temporal sequence. Graesser, Hoffman and Clark (1980) found that schemas facilitated recall in "narrative passages" but not in "technical passages".

2.8.: The representation-saving theory:

A number of authors explain the prior knowledge effect by the phenomenon of representation-saving (Kieras, 1977, Anderson and Bower, 1973, Johnson and Kieras, 1983). What they mean by this is that the more a person has prior knowledge about a subject the more propositions he has in his memory that are already part of the new information and consequently do not need to be encoded. The effort required for encoding is then superfluous or considerably reduced. Before the encoding of each proposition a check is carried out in order to see whether it is already in the long term memory or not. More prior knowledge leads to a more rapid processing of the information. This hypothesis forecasts the degree of encoding effort, the learning time, and shows a linear relationship with the number of propositions that the experimental subject already knows. This explanation leans, according to Johnson and Kieras (1983), heavily on the elaboration theory.

In order to give a clear synopsis of the various theories they are summarized in table 1.:

Table 1 : Theoretical views of the facilitating effect of prior knowledge during the learning process.

Theory	How does prior knowledge influence the learning process? (key concept)
1.Restructuring	Information is structured in a different way in the LTM. (Structure)
2.Elaboration	The production of elaborations leads to multiple redundant retrieval paths in the cognitive representation. (Elaboration)
3.Accessibility	Prior knowledge increases the accessibility of knowledge and consequently the load on the working memory is reduced and more information can be processed per time unit. (Rapidity)
4.Selective attention	Attention is directed selectively at passages relevant to prior knowledge, which are subjected to a deeper level of processing. (Selection, steering)
5.Availability	Prior knowledge increases the availability of information during the learning process and leads to a higher level of retention. (Availability)
6.Retrieval-aid	Prior knowledge and access to relevant cognitive structures increases retrieval. (Retrieval)
7.Schema-transfer	Prior knowledge implies the presence of relevant schemes, the new information has to be fit in the right scheme. (Couple information-scheme)
8.Representation saving	Propositions which are part of the prior knowledge no longer have to be encoded. The encoding effort is in consequence considerably reduced. (Proposition)

It is not our intention to comment on the tenability of these various theories. This would also not appear to be immediately possible. A number of theories lean heavily on one or the other or show a degree of overlap. The different theories are not necessarily mutually exclusive; they are primarily concerned with phases that follow one another in information processing. Accordingly, prior knowledge is said to influence each of these phases: the direction of attention, the encoding of information, its processing in the working memory, storage in the long term memory, and recovery of information from the long term memory.

It is striking that the research referred to makes considerable use of the activation of prior knowledge and not of the prior knowledge itself. In experimental situations, a short text or task is offered as an independent variable. We are more interested in the impact of students' real prior knowledge on the learning process and learning results. Further, virtually all the research into prior knowledge is characterized by a very limited ecological validity. This means that the experimental environment is so constructed that the research results cannot be generalized from it to real educational situations. Experiments use lists of words or one or two short sentences as the information that the student must learn. Prior knowledge is activated by short passages of text. The information to be learnt deals with fictional subjects (for example the American "desert fox"; Peeck, van den Bosch and Kreupeling, 1982) or non-existing situations (for example the balloon study of Bransford and Johnson (1972). Finally the nature of the test (general questions or specific questions on the text, recognition or remembering, etc.) is seldom taken into account in the interpretation of the results.

The supporters of the transfer appropriate processing approach (Morris, Bransford, Franks, 1977; Bransford, Franks, Morris and Stein, 1979) believe that the nature of the test should be included in every consideration. It seems self-evident that varying performances would be achieved if the test were not to relate to the learning task. Although the reproduction of facts is an easy goal it is certainly not the most important and there are many serious objections to a simplistic encouragement of this sort of learning. (Ausubel, 1968; Bruner, 1959; Holt, 1969; Ormell, 1979; Dochy and Van Luyk, 1987).

According to Bransford et al., it is not so much a question of the quantitative relationship between the amount of retention and number of elaborations, but more of the qualitative relationship between the nature of the processing activities and the nature of the learning results.

These different theories recognize the positive influence of prior knowledge on the selection process from the knowledge base, the capacity of the working memory, the elaborations carried out on new information, the storage of new

information in the LTM and the retrieval of new information. It would seem likely that prior knowledge (or parts of it) not only affects the learning process, but also the learning results.

3. The significance of the concept "prior knowledge".

3.1. The definition of "prior knowledge".

The concept "prior knowledge" is difficult to define. In the English speaking world, in which the phenomenon is most widely studied, various terms are used interchangeably. "Prior knowledge" is used, but there are also terms such as 'prestorage', 'permanent stored knowledge', 'prestored knowledge', 'knowledge store', 'prior knowledge state', 'prior knowledge state in the knowledge base', 'implicit knowledge' or 'archival memory'. Explanations of these terms are however few and far between. Neisser (1976) talks about the role of prior knowledge in perception. He describes prior knowledge as the skills and experience of the observer or, further, as what he knows in advance. There is not much more than this type of vague definition to be found in the literature. Nevertheless it would seem necessary to arrive at a stricter description. An exploration and conceptualization of various types of knowledge will provide more concrete information for this purpose.

3.2. Types of prior knowledge.

In cognitive psychology, knowledge is operationalized by means of a number of concepts. A number of cognitivists use the dichotomy of declarative and procedural knowledge, others talk of episodic and semantic knowledge. Still others talk about the use of strategic knowledge. It is possible not only to make a distinction in terms of the content of the prior knowledge, but also in terms of the scope of the area of knowledge to which it refers.
In this context, domain specific knowledge or domain independent prior knowledge is used. These differences will be explained briefly below.

Declarative knowledge and procedural knowledge.

Conceptual knowledge (Posner, 1978), largely called declarative knowledge, is the knowledge of facts, the meanings of symbols and the concepts and principles of a particular field of study. Cohen (1983) even limits this to facts. Sometimes propositional knowledge is referred to (Greeno, 1980) or descriptive knowledge (Lodewijks, 1981).

Knowledge of action, manipulation and activities are indicated by De Jong (1986) as procedural knowledge. Cohen (1983) talks of skills, rules, procedures and plans.

The distinction between declarative and procedural knowledge.

The essential difference between these two is that procedural knowledge refers directly to action or activity, while declarative knowledge requires an interpretation in order to lead to action (Messick, 1984). Anderson (1980) gives the distinction declarative - procedural again as "knowing that" and "knowing how" respectively. Cognitive skill is in close relation to procedural knowledge and is described as the ability to carry out various intellectual procedures (Anderson, 1980). A less absolute distinction is made by Anderson (1980) in saying that most declarative knowledge can be expressed verbally while much procedural knowledge cannot.... However, declarative knowledge need not be verbal". There are two currents of scholarly research into 'machine intelligence': to the first, the proceduralists, knowledge is procedural and is concerned with how; and for the second, the declarativists, knowledge includes both propositions ('knowing what') and general procedures to manipulate them. As far as human knowledge is concerned, the declarativists are right, according to Cohen (1983). It is reasonable to assume that procedural knowledge is less domain specific. People's knowledge base is regularly added to, adjusted, amended and old knowledge is often used in a new way, making it defensible to assume that the declarative form of the representation of knowledge offers more advantages.

Episodic knowledge and semantic knowledge.

Episodic knowledge reflects the totality of personal experience in its spatio-temporal context, and is comparable to an historical document. Episodical knowledge is contextual and accidental. Semantic knowledge includes a representation of the external world, abstracted from its context and is permanent and necessary. This knowledge is largely expressed in 'models of memory' as a system of related concepts, including what are called 'nodes'.

The relationship between episodic and semantic knowledge.

According to Cohen (1983) in practice there is no sharp distinction between the types of knowledge. Each model which makes a distinction must also be provided with an interface between episodic and semantic knowledge. How often do we have to see a leopard to know that its spots are a defining characteristic? 'Permanent stored knowledge' arises on the basis of new episodic inputs.

Strategic knowledge.

Strategy can be seen as a general plan of action in which the sequence of the separate cognitive activities is laid down (Posner and McLeod, 1982). This is primarily important in the solution of problems in which the following different phases have to be gone through: analysis, planning, implementation and verification (Schoenfeld, 1979; Mettes and Pilot, 1980). Strategic knowledge directs the thinking process, but the boundaries to the use of this knowledge are thus far unclear. For that reason there are no explicit theories, as yet, on the content of this knowledge (Brown, Collins and Harris, 1978). The conceptualization of this type of knowledge is very vague. Cohen (1983) makes no distinction between it and procedural knowledge. Both comprise skills and plans of action.
According to De Jong (1986) the difference resides in the degree of specificity. Procedures related to a small part of the solution process are largely domain specific, and include algorithms and heuristic devices. Strategies are related to the whole process of solution and are often used more with subject content (Schoenfeld, 1983; De Jong, 1986). There is, however, never a question of a strict dichotomy, but rather of a sliding transition. After all, the terms, procedural and strategic, are often used interchangeably.

Domain specific knowledge and domain transcending knowledge.

Recent research has pointed the fact that both domain specific knowledge and domain transcendant knowledge exists in the knowledge base (Glaser, 1984). Furthermore there is evidence that learning is far more domain specific than earlier theorists of learning believed (Shuell, 1986; Tuma and Reif, 1980). Carey (1985) suggests that the acquisition of knowledge during the total period of development is based on increasing knowledge within various domains. This 'domain specific restructuring view of development' has received a great deal of support in research on novice-expert differences within various domains, such as physics (Chi, Glaser and Rees, 1982; Larkin, McDermott, Simon and Simon, 1981; McCloskey, Caramazza and Green, 1980), chess (Chase and Simon, 1973), radiology (Lesgold, Feltovich, Glaser and Wang, 1981) and the social sciences (Voss, Greene, Post and Penner, 1983). Nevertheless it is unlikely that all learning is domain specific. If this were the case, it would be difficult to explain how individuals deal with new situations or how they handle entirely new information. Viewed objectively, learning, according to Shuell (1986), comprises domain specific and domain independent processes. How these processes interfere with one another is as yet unclear.

Glaser's hypothesis (1984) is that relative emphasis on specific or more transferable knowledge in instructions will vary as a function of the competence (or prior knowledge) of the learner and the characteristics of the domain. According to the expert, Robert Glaser, a useful approach to research is to learn the domain specific knowledge so that the more general (self-regulatory) skills are practiced during this learning (Glaser, 1984).

Conclusion.

On the basis of the positions taken above, research results and new developments in cognitive psychology, it would appear useful to define the concept of 'prior knowledge' and to describe it as a 'domain specific prior knowledge state'. This indicates that the concern is with domain specific knowledge at a particular moment, in this case prior to learning an assigned learning task.
By 'knowledge state' we are to understand the entirety of the domain specific knowledge and skills, available before learning. This comprises both declarative and procedural knowledge. Bransford (1979) speaks of the "current level of previously acquired knowledge and skills".

3.3. Differences in prior knowledge

A well known distinction in prior knowledge, often made in cognitive psychology, is that between the expert and the novice. Norman (1978) describes an expert as someone who has studied a complex subject for a period of 5000 hours, and during that time has thought about it on a daily basis and has also learned to use the information. The distinction between a novice and an expert resides in the amount of prior knowledge which they have at their disposal. The difference in prior knowledge or expertise influences the manner in which they learn. Mirande (1981) gave a psychology text to a beginning student and an expert, and asked them to draw up a schema of the text and a list of specifications of the concepts used. In studying the text, the student approached it on the basis of: what can I learn from this text? He added new knowledge to his stock of knowledge. The expert asked: how is this subject dealt with? During the reading process she was continually assessing, and comparing the knowledge in the text with her own knowledge. In schematizing the expert included more concepts in her scheme than the student, while her list of specifications had an entirely different content. The abbreviated schemas of the student (see diagram 3) and of the expert (see diagram 4) show how markedly their accounts differed. For the student it is a text about three sorts of tests. For the expert it is a text about three critical observations on part of a text about tests by a particular author.

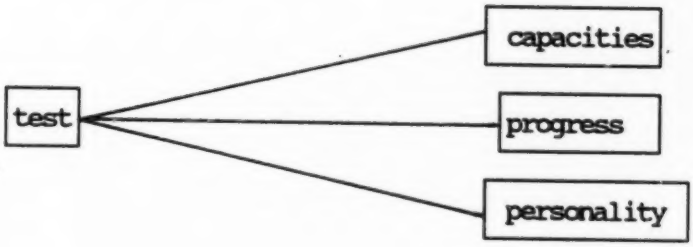

Figure 3: The abbreviated scheme of the student (Mirande, 1981)

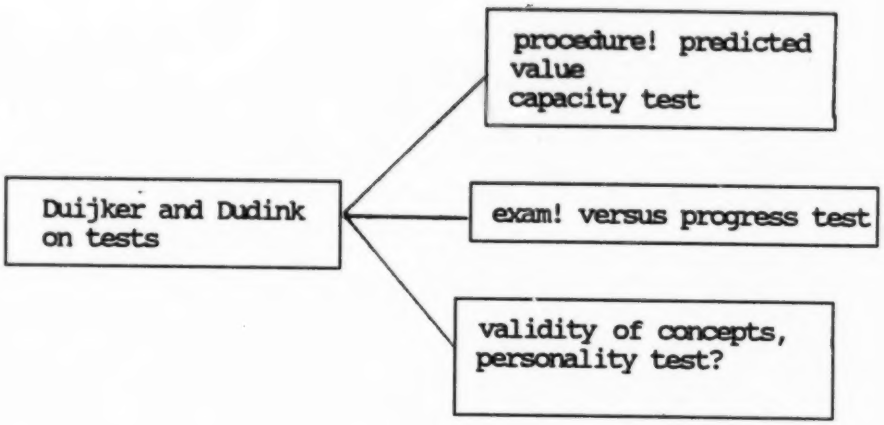
Duijker and Dudink on tests
procedure! predicted value capacity test
exam! versus progress test
validity of concepts, personality test?

Figure 4: Schema of the expert (Mirande, 1981)

Research into the differences between novices and experts. Differences between novices and experts were primarily investigated in respect of the solution to problems. Chi, Feltovich and Glaser (1981) carried out three experiments in which problems in mechanics were offered for solution.

They concluded that experts had a different cognitive structure, comprising what are called problem schemata. An adequate problem schema includes elements of declarative and procedural knowledge which are valid for that specific type

of problem, in addition to knowledge of problem situations. In listing everything that is of use in the solution of various sorts of problem, experts and novices mentioned the characteristics of problem situations equally frequently. Experts appeared however to be able to name more explicit procedures (if-when relations). Chi and others (1981) concluded from this that experts have explicit solution procedures in their specific problem schemata, related to the characteristics of problems. Larkin, McDermott, Simon and Simon (1980) and Elshout (1982) discovered that experts are more thorough in their analysis of the problem. Beginners appeared to jump quickly to the solutions and omit stages in the analysis and transformation which experts pay attention to. According to Larkin et al. (1980), Chi et al. (1982) and Been and Brokken (1984) in the statement of the problem, experts are able to more easily discover the characteristics relevant to the selection of the solution procedure. Experts also make fewer errors and reach a solution more efficiently by means of a 'means-end analysis', (Larkin et al., 1980). Analogous expert - novice differences were discovered in both the solution of natural science problems and in the positing of a medical diagnoses (Schmidt, 1982, Dijkstra, van der Stelt, van der Seijde, 1983). Differences between experts and novices can be reduced to the following differences in knowledge and skills (Reif, 1981; Jansweijer and Elshout, 1984; Mettes, 1984):

a. Differences in methods of problem analysis.
   The novice does not have:
   - a canon of models of problem schemata
   - an analytical of categorization system for problems.

b. There are differences in declarative knowledge.
   - this knowledge is more complete and more coherent in the expert
   - the beginner fills in the missing knowledge with naive knowledge and ad hoc theories of ideosyncratic proposals for processes or states.

c. Differences in procedural knowledge.
   - the expert has better organized more wide ranging production schemata, associated with more explicit conditions for application and categories of problem situations.
   - the expert's knowledge is structured so that the same information (the declarative information too) is present at different levels of detail.
   - the beginner does not have a systematic solution plan.
   - the beginner has problems with the application of general knowledge in specific situations.

Limited power of generalization and complaints against the expert-novice paradigm.

The results of the above research have to be interpreted with a degree of caution. One of the reasons for this is that they are virtually exclusively concerned with research into problem solution and not with learning as a whole. Secondly the research primarily concerns problems of natural science and medical problems and furthermore problems at a relatively simple level. i.e. well defined problems of a specification type (Mettes and Pilot, 1980; Schmidt, 1982). Furthermore, caution in interpretation is recommended because the expert-novice paradigm is not a true paradigm. Let us add something to this. In the research above, beginning students are largely used as novices, staff or graduates as experts. But who is a novice and when does one become an expert? People who have completed their education in a subject or have a number of years experience in that area are taken to be experts. Graduates, teaching staff, professors, but also students who have pursued a course, and have studied with success are also regarded as experts (Jansweijer, Elshout and Wielinga, 1985). So there can be a great deal of difference between different experts. Furthermore, being an expert is related to a field of study or domain specific knowledge. An expert in education can be a novice in chemistry.
Determining the beginner's level of expertise, however, seems to be much more arbitrary. In the research of De Groot (1946), Dijkstra et al. (1983), Chi et al. (1981) and Larkin (1979), the novice experimental subjects already had a certain amount of expertise in the domain (De Jong, 1986). In other research, such as that of Egan and Schwartz (1979), Mourant and Rockwell (1972) and Shavelson (1972, 1973, 1974) beginners were categorized as being 'uninformed', 'having little knowledge' or 'an almost complete lack of experience'. Beginners are thus defined at different levels and are virtually incommensurable as a homogeneous group. Gradually an understanding is beginning to dawn, i.e. that beginners, certainly when defined as those who have acquired some insight into the domain, are a heterogeneous research population. With this in mind, Silver (1981), Finegold and Mass (1985) and De Jong (1986) investigated the differences between weak and good beginning problem solvers. Finally, in respect of the power of generalization of these research results, note should be taken of the often rather small number of experimental subjects; two to eight would appear to be the average. Also of the fact that on judging the protocols, the assessors were often informed of the level of expertise of the experimental subjects. This is also important. It is certainly relevant when there is no validity test of the assessments.

4. Conclusion

In the last decade, research has clearly shown that the 'Prior Knowledge State' of the student has a strong influence on learning.
Eight different theories explain this phenomenon by assigning a positive influence to prior knowledge on the selection process from the knowledge base, the capacity of the working memory, the elaboration carried out on new information, the storage of new information in the LTM and retrieval of new information. These theories are still hypothetical however.

Prior knowledge can be defined as 'Prior Knowledge State': the totality of domain specific knowledge and skills available for the execution of particular learning activity. One can also speak of part declarative, part procedural knowledge.
Differences in prior knowledge, operationalized in the expert - novice paradigm must be interpreted with necessary caution. It is not a true paradigm.

In contradistinction to the influence of prior knowledge in the learning process, in education relatively little account is taken of the prior knowledge and experience of students. In the temporal and content grading of subjects, only seldom account is taken of prior knowledge. At the most we can speak of a setting off of what is largely presumed and only in some few cases tested prior knowledge.

Finally there is the empirically demonstrated phenomenon, of the facilitating effect of PKS, which is primarily based on a strict experimental research at a micro level. There is need for more ecologically valid research or more applied research and a satisfactory explanation with a concrete usable theory.

Literatuur.

Anderson, J.R. (1976). Language, Memory and Thought. Hillsdale:Lawrence Erlbaum.

Anderson, J.R. (1980). Cognitive Psychology and its Implications. San Francisco: W.H.Freeman and Company.

Anderson, J.R. and Bower, G.H. (1973). Human associative memory. Washington, D.C.: Winston.

Anderson, R.C. and Pinchert, J.W. (1978). Recall of previously unrecallable information following a shift in perspective. Journal of Verbal Learning and Verbal Behavior, 17, 1-12.

Anderson, R.C., Pichert, J.W., Shirey, L.L. (1983). Effect's of the reader's schema at different points in time. Journal of Educational Psychology, 75, 271-279.

Anderson, J.R., and Reder, L.M. (1979). An elaborative processing explanation of depth of processing. In .S. Cermak and F.I.M. Craik (Eds.). Levels of processing in human memory. Hillsdale: Lawrence Erlbaum.

Anderson, R.C., Spiro, R.J., Montaque, W.E. (1977). Schooling and the acquisition of knowledge. Hillsdale, N.J.: Erlbaum, London: Wiley.

Anderson, R.C., Spiro, R.J. and Anderson, M.C. (1978). Schemata as scaffolding for the representation of information in connected discourse. American Educational Research Journal, 15, 433-440.

Ausubel, D.P. (1960). The use of advance organizers in the learning and retention of meaningful verbal material. Journal of Educational Psychology, 51, 267-272.

Ausubel, D.P. (1968).Educational Psychology: a cognitive view.
New York: Holt, Rinehart and Winston.

Bartlett, F.C., (1932). Remembering: A study in experimental and social psychology. London: Cambridge University Press.

Been, P.H., en Brokken, F.B., (1984). Kategorisering van statistiekproblemen door beginners en experts. R.U. Groningen: COWOG/Interd. Onderwijskunde.

Berman, J.S., Read, S.J., Kenny, D.A. (1983). Processing inconsistent social information. Journal of Personality and

Social Psychology, 45, 1211-1224.

Bloom, B.S., (1976). Human characteristics and school learning. New York: McGraw-Hill.

Bower, G.J., Black, J.B., and Turner, T.J., (1979). Scripts in comprehension and memory. Cognitive Psychology, 11, 177-220.

Bransford, J.D., (1979). Human cognition. Belmont, Californië: Wadsworth.

Bransford, J.D, and Johnson, M.K., (1972). Contextual Prerequisites for Understanding: Some Investigations of Comprehension and Recall. Journal of Verbal Learning and Verbal Behavior, 11, 717-726.

Bransford, J.D., Franks, J.J., Morris, C.D. and Stein, B.S.(1979). Some general constraints on Learning and memory research . In: L.S. Cermak and F.I.M. Craik (Eds.). Levels of processing in human memory. Hillsdale,N.J. : Lawrence Erlbaum Associates.

Brewer, W.F., and Nakamura, G.V., (1984). The nature and functions of schemas. In: Wyer, R.S., and Srull, T.K., Handbook of social Cognition, 1, 119-160. Hillsdale: Erlbaum.

Brown, J.S., Collins, A., and Harris, G., (1978). Artificial intelligence and learning strategies. In H.O'Neil (Ed.), Learning strategies. New York: Academic Press.

Bruner, J.S. (1957). Learning and Thinking. Havard Educational Review, 29, 184-188.

Carey, S., (1985). Are children fundamentally different kinds of thinkers and learners than adults? In S.F. Chipman, J.W. Segal and R.Glaser (Eds.). Thinking and learning skills, 2, 485-517. Hillsdale, N.J.: Erlbaum.

Chase, W.G., and Simon, H.A., (1973). Perception in chess. Cognitive Psychology, 4, 55-81.

Chi, M.T., Feltovich, P.J., and Glaser, R., (1981). Categorization and representation of physics problems by experts and novices.Cognitive Science, 5, 121-152.

Chi, M.T.H., Glaser, R., and Rees, E., (1982). Expertise in problem solving. In R. Sternberg (Ed.). Advances in the psychology of human intellegence, 7-76. Hillsdale, N.J.: Erlbaum.

Chiesi, H.L, Spilich, G.J., and Voss, J.F., (1979). Acquisition of domain related information in relation to high and low domain knowledge. Journal of Verbal Learningd and Verbal Behavior, 18, 257-273.

Cohen, G., (1983). The Psychology of cognition. London - New York: Academic Press.

Cohen, C.E., (1981). Person categories and social perception: Testing some boundaries of the processing effects of prior knowledge. Journal of Personality and Social Psychology, 40, 441-452.

Craik, F.I.M., and Lockhart, R.S., (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671-684.

Craik, F.I.M., and Tulving, E., (1975). Depth of processing and the retention of words in episodic memory. Journal of Experiental Psychology, 104, 268-294.

Crowder, R.G., (1976). Principles of learning and memory. Hillsdale, New Jersy: Lawrence Erlbaum.

Dam, G. van, (1979). De invloed van theoretische ontwikkelingen in de psychologie op de methoden van het onderzoek naar het onthouden van teksten. Tijdschrift voor Taalbeheersing, 1, 61-74.

Davey, B., Kapinus, B.A., (1985). Prior knowledge and recall of unfamiliar information: reader and text factor. Journal of Educational Research, 78 (3) 147-151.

Dijkstra, S., Van der Stelt, P.F., en Van der Sijde, P.C., (1983). Het effect van verschillende expertise-niveaus op de interpretatie van tandheelkundige röntgenfoto's. In J.J. Beishuizen, C. Hamaker, B. Van Hout-Wolters and K.B. Koster (Eds.), Onderwijsprocessen (78-83). Lisse: Swets en Zeitlinger.

Dochy, F.J.R.C. & Luyk, S.J., van, (1987). Handboek Vaardigheidsonderwijs. Lisse: Swets & Zeitlinger.

Egan, D.E., and Schwartz, B.J., (1979). Chunking in recall of symbolic drawings. Memory and Cognition, 7 (2), 149-158.

Elshout, J.J., (1982). Een beginner is méér dan iemand die het nog niet kan, Voordracht Psychologencongres okt.1982. Amsterdam. ICO-rapport 304 J.E. dec.1982. Amsterdam: Universiteit van Amsterdam.

Finegold, M. and Mass, R., (1985). Differences in the processes of solving physics problems between good physics problem solvers and poor physics problem solvers. Research in Science and Technological Education, 3, 59-67.

Francks, J.J., Vye, N.J., Auble, P.M., Mezynski, K.J., Perfetto, G.A., Bransford, J.D., Stein, B.S., and Littlefield, J. (1982). Learning from explicit versus implicit text. Journal of Expereimental Psychology.General, 111, (4), 414-422.

Frederiksen, C.H., (1975). Representing logical and semantic structure of knowledge acquired from discourse. Cognitive Psychology, 7, 371-458.

Gagné, E.D. (1978). Long-term retention of information following learning from prose. Review of Educational Research, 48, 629-665.

Gerritsen van der Hoop, J.W. (1986). Het onderwijzen van theoretische begrippen waarover de leerling zelf al opvattingen heeft (dissertatie). Eindhoven: Technische Hogeschool Eindhoven.

Glaser, R. (1984). Education and Thinking. The role of knowledge. American Psychologist, 39, 93-104.

Goetz, E.T., Schallert, D.L., Reynolds, and Radin, D.I., (1983). Reading in perspective: What real cops and pretend burglars look for in a story. Journal of Educational Psychology, 75, 500-510.

Graesser, A.C., Hoffman, N.L., Clark, L.F. (1980). Structural components of reading time. Journal of verbal learning and verbal behavior, 19, 131-151.

Graesser, A.C., Robertson, S.P. and Anderson, P.A., (1981). Incorporating inferences in narrative representations: A study of how and why. Cognitive Psychology, 13, 1-26.

Graesser, A.C., Woll, S.B., Kowalski, D.J. and Smith, D.A., (1980). Memory for typical and atypical actions in scripted activities. Journal of Experimental Psychology: Human Learning and Memory, 6, 503-515.

Greeno, J.G., (1980). Trends in the theory of knowledge for problem solving. In D.T. Tuma and F.Reif (Eds.), Problem solving and education (9-25). Hillsdale,N.J.: Lawrence Erlbaum.

Groot, A.D. de, (1946). Het denken van den schaker. (dissertatie).Amsterdam:Noord-Hollandse Uitgevers maatschappij.

Groot, A.D. de, (1978). Thought and choice in chess (2nd Ed.). Mouton, Den Haag.

Hastie, R., (1980). Memory for information that confirms or contradicts a general impression. In R.Hastie, T.M. Ostrom, E.B. Ebbesen, R.S. Wyer, D.L. Hamilton and D.E. Carlston. Person memory: The cognitive basis of social perception. Hillsdale, New Jersey, Lawrence Erlbaum.

Hastie, R. and Kumar, P.A., (1979). Person memory: Personality traits as organizing principles in memory for behaviors. Journal of Personality and Social Psychology, 37, 25-38.

Holt, J., (1969). How children fail. Utrecht: Penguin Books.

Jansweyer, W.N.H. en Elshout, J.J., (1984). Het leren van de beginnende probleemoplosser,Tilburg: Paper ORD 1984.

Jansweijer, W.N.H., Elshout, J.J., en Wielinga, B.J., (1985). Het leren van de beginnende probleemoplosser. In J.G.L.C. Lodewijks en P.R.J. Simons (Eds.), Zelfstandig leren (102-110). Lisse:Swets en Zeitlinger.

Johnson, R.E. (1973). Meaningfulness and the recall of textual prose. American Educational Research Journal, 10, 49-58.

Johnson, W. and Kieras, D., (1983). Representation-saving effects of prior knowledge in memory for simple technical prose. Memory and Cognition, 11 , 456-466.

Jong, T. de, (1986). Kennis en het oplossen van vakinhoudelijke problemen. Proefschrift Technische Hogeschool Eindhoven. Helmond: Wibro.

Kieras, D.E., (1977). Problems of reference in text comprehension. In M. Just and P. Carpenter (Eds.), Cognitive processes in comprehension. Hillsdale,N.J.:Erlbaum.

Larkin, J.H. (1979). Processing information for effective problem solving. Engineering Education, 285-288.

Larkin, J.H., Mc. Dermott, J., Simon, D.P., Simon, H.A., (1980). Expert and novice performance in solving physics problems. Science, 208, 1335-1342.

Larkin, J.H., Mc. Dermott, J., Simon, H.A. and Simon, D.P., (1981). Models of competence. Cognitive Science, 4, 317-345.

Lesgold, A.M., Feltovich, P.J., Glaser, R. and Wang, Y., (1981). The aquisition of perceptual diagnosic skill in radiology. Pittsburg, P.A.: University of Pittsburg, Learning Research and Development Center.

Lodewijks, J.G.L.C., (1981). Leerstofsequenties van conceptueel netwerk naar cognitieve structuur.(dissertatie). Katholieke Hogeschool Tilburg. Lisse: Swets en Zeitlingen.

Lodewijks, H. (1983). Van conceptueel netwerk naar cognitieve structuur. Lisse: Swets & Zeitlinger.

Matthews, S.R., (1982). The impact of prior knowledge on accessibility and availability on information from prose. In A. Flammer and W. Kintch (Eds.). Discourse Processing.Amsterdam: North-Holland.

Mayer, R.E., (1979). Twenty years of research on advance organizers. Instructional Science, 8, 133-167.

Mayer, R.E., (1980). Elaboration techniques that increase the meaningfulness of technical text: an experimental test of the learning strategy hypothesis. Journal of Educational Psychology, 72,770-784.

Mc.Closkey, M., Caramazza, A. and Green, B., (1980). Curvilineair motion in the absence of external forces: Naive beliefs about motion of objects. Science, 210, 1139-1141.

Messick, S., (1984). The Psychology of educational measurement. Journal of Educational Measurement, 21(3) , 215-237.

Mettes, C.T.C.W., (1984). Probleemoplossen en onderwijs. In L.F.W. de Klerk en A.M.P. Knoers (red.). Onderwijspsychologisch onderzoek. Lisse: Swets & Zeitlinger.

Mettes, C.T.C.W. en Pilot, A., (1980). Over het oplossen van natuurwetenschappelijke problemen.(dissertatie). Enschede: Onderwijskundig Centrum CDO/AVC.

Mirande, M.J.A., (1981). Studeren door schematiseren. Utrecht/ Antwerpen: Het Spectrum.

Morris, C.D., Bransford, J.D. and Franks, J.J., (1977). Levels of processing versus transfer appropriate processing. Journal of Verbal Learning and Verbal Behavior, 16, 519-533.

Mourant, R.R., and Rockwell, T.H., (1972). Strategies of visual search by novice and eexperienced drivers. Human factors, 14, 325-335.

Neisser, U., (1976). Cognition and Reality. San Francisco: W.H. Freeman.

Norman, D.A., (1978). Notes toward a theory of complex learning. In Les Gold, Pellegrino, Fokkema and Glaser (eds.). Cognitive psychology and instruction. New York: Plenum Press.
Ornell, C.P., (1979). the problem of analysing understanding. Educational Research, 22, 32-38.

Pace, A.J., (1978). The influence of world knowledge on children's comprehension of short narrative passages. Paper presented at the Annual Meeting of the AERA, Toronto, Canada.

Paivio, A., (1971). Imagery and Verbal Processes. New York,Holt: Rinehart and Winston.

Peeck, J. (1979). Voorkennis en tekstbestudering. Tijdschrift voor Taalbeheersing, 1, 301-313.

Peeck, J., Van der Bosch, A.B., en Kreupeling, W.J. (1982). Effect of mobilizing prior knowledge on learning from text. Journal of Educational Psychology, 74, 771-777.

Phillips, J.S. and Lord, R.G., (1982). Schematic information processing and perceptions of leadership in problem-solving groups. Journal of Applied Psychology, 67, 486-492.

Pinchert, J.W., and Anderson, R.C., (1977). Taking different perspectives on a story. Journal of Educational Psychology, 69, 305-315.

Posner, G.M., (1978). Cognitive science:Implications for curriculum research and development. Paper presented at the AERA conference, Toronto.

Posner, M.I., and Mc.Leod, P., (1982). Information processing models, in search of elementary operations. Annual Review of Psychology, 33, 477-514.

Reder, L.M., (1980). The role of elaboration in the comprehension and retention of prose : a critical review. Review of Educational Research, 50, 5-53.

Reif, F., (1981). Teaching problem solving,a scientific approach. The Physics Teacher, May 1981, 310-316.

Reynolds, R.E., Standiford, S.N., and Anderson, R.C. (1979). Distribution of reading time when questions are asked about a restricted category of text information. Journal of Educational Psychology, 71, 183-190.

Rothbart, M., Evans, M. and Fulero, S., (1979). Recall for confirming events: Memory processes and the maintenance of social stereotypes. Journal of Experimental Social Psychology, 15, 343-355.

Rothkopf, E.Z., and Billington, M.J., (1979). Goal-guided learning from text: inferring a descriptive processing model from inspection times and eye movements. Journal of Educational Psychology, 71, 310-327.

Royer, J.M. and Cable, G.W., (1975). Facilitated learning in connected discourse. Journal of Educational Psychology, 67, 116-123.

Rumelhart, D.E., (1980). Schemata:The building blocks of cognition. In R.Spiro,B.Bruce and W.Brewer (Eds.), Theoretical issues in reading comprehension. Hillsdale,N.J.:Erlbaum.

Rumelhart, D.E. and Ortony, A., (1977). The representation of knowledge in memory. In R.C.Anderson, R.J. Spiro and E. Montague (Eds.),Schooling and the acquisition of knowledge. Hillsdale,
N.J.: Erlbaum.

Schank, R.C., en Abelson, R.P. (1977). Script, plans, goals and understanding: An inquiry into human knowledge structures. Hillsdale (N.J.): Lawrence Erlbaum Ass.

Schmidt, H.G., (1982). Activatie van voorkennis en een "verschuivings" effect bij het onthouden van tekst. Rijksuniversiteit Limburg, Maastricht.

Schmidt, H.G., (1982). Activatie van voorkennis, intrinsieke motovatie en de verwerking van tekst. Apeldoorn: Van Walraven.

Schmidt, H.G., (1987). Waarom zijn studievaardigheidscursussen zo weinig effectief? Tijdschrift voor hoger onderwijs, 5 (3), 112-116.

Schoenfeld, A.H., (1979). Can heuristics be taught? In J. Lochhead and J. Clement (Eds.), Cognitive process instruction. 315-338. Philadelphia : The Franklin Institute Press.

Schoenfeld, A.H. (1983). Episodes and executive decisions in Mathematical problem-solving. In R. Lesh en M. Landau (eds.) Acquisition of mathematics concepts and processes (345-397). New York: Academic Press.

Shavelson, R.J., (1972). Some aspects of the correspondence between content structure and cognitive structure in physics instruction. Journal of Educational Psychology, 63 (3), 225-234.

Shavelson, R.J., (1973). Learning from physics instruction. Journal of Research in Science Teaching, 10 (2), 101-111.

Shavelson, R.J., (1974). Methods for examining representations of a subject-matter structure in a students memory. Journal of Research in Science Teaching, 11 (3), 231-249.

Shuell, T.J., (1986). Cognitive Conceptions of Learning. Review of Educational Research, 56, 411-436. State University of New York at Buffalo.

Silver, E.A., (1981). Recall of mathematical fproblem information: Solving related problems. Journal for Research in Mathematics Educdation, 12 (1), 54-64.

Spilich, G.J., Vesonder, G.T., Chiesi, H.L., and Voss, J.F. (1979).Text processing of domain-related information for individuals with high and low domain knowledge. Journal of Verbal Learning and Verbal Behavior, 18, 275-291.

Srull, T.K. (1981). Person memory: Some tests of associative storage and retrieval models. Journal of verbal learning and memory, 7, 440-463.

Stein, B.S., Bransford, J.D., Franks, J.J., Owings,R.A., Vye, N.J. and Mc Graw, W. (1982). Differences in the precision of self-generated elaborations. Journal of Experimental Psychology: General, 111 (4), 339-405.

Thorndyke, P.W., (1977). Cognitive structures in comprehension and memory of narrative discourse. Cognitive Psychology, 9, 77-110.

Tulving, E. and Thomson, D.M., (1973). Encoding specificity and retrieval processes in episodic memory. Psychological Review, 80, 352-373.

Tuma, D.T. and Reif, F. (Eds.). (1980). Problem solving and education: Issues in teaching and research. Hillsdale, N.J.: Erlbaum.

Vosniadou, S. and Brewer, W.F., (1987). Theories of Knowledge Restructuring in Development. Review of Educational Research, 57, 51-67. University of Illinois at Urbana-Champaign.

Voss, J.F., Greene, T.R., Post, T.A. and Penner, B.C. (1983). Problem - solving skill in the social sciences. In G.H. Bower (Ed.). The psychology of learning and motivation: Advances in research and theory, 17, 165-213. New York: Academic Press.

Weeda, W.C. (1982). Beheersingsleren: het model getoetst in de tijd. Academisch proefschrift Tilburg: Katholieke Hogeschool.

Wolf, H.C. de, (1985). Open onderwijs of de voortdurende beweging van lerende mensen. Heerlen, Open Universiteit: Samsom uitgeverij.

Zwarts, J. (1979). Het effect van voorkennis op het bestuderen van een tekst. Doctoraal scriptie. Psychologie Laboratorium, R.U. Utrecht.